CMR INSTITUTE OF TECHNOLOGY

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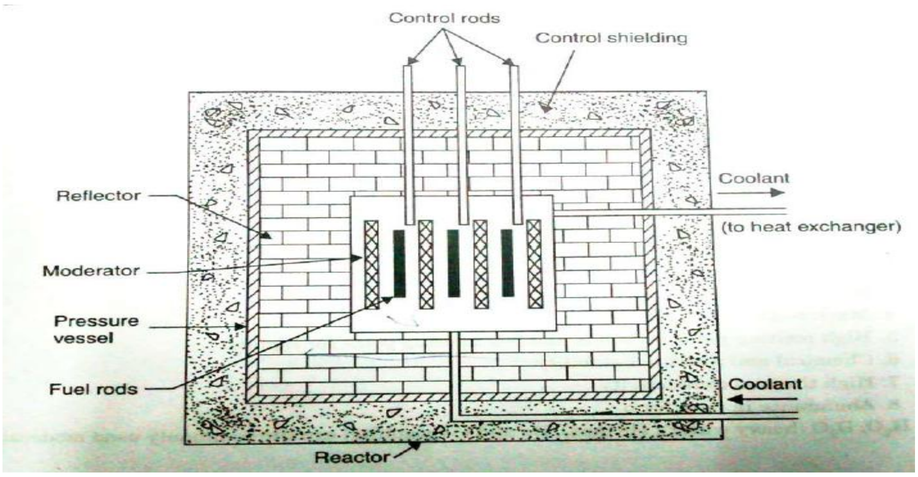
Internal Assesment Test - III

| Sub: | Power Generation and Economics | | | | | | | Code: | 17EE42 |
|---|---|---|---|---|---|---|---|---|---|
| Date: | 15/05/2019 | Duration: | 90 mins | Max Marks: | 50 | Sem: | 4 | Branch: | EEE |
| Answer Any FIVE FULL Questions | | | | | | | | | |

| | | Marks | OBE CO | OBE RBT |
|---|---|---|---|---|
| 1.a | With neat diagram explain the working of main parts of nuclear reactor. | [6] | CO2 | L1 |
| 1.b | Discuss the advantages and disadvantages of nuclear power plant. | [4] | CO2 | L2 |
| 2.a | Give the various classifications of nuclear reactor and explain any one. | [7] | CO2 | L1 |
| 2.b | List out are the advantages and disadvantages of fast reactors? | [3] | CO2 | L2 |
| 3.a | Describe the operation of nuclear power plant with the help of block diagram showing basic components | [7] | CO2 | L1 |
| 3.b | Discuss the factors for the choice of site for a nuclear power plant. | [3] | CO2 | L2 |
| 4.a | Explain with respect to nuclear power plant: (i) nuclear waste disposal, (ii) shielding | [6] | CO2 | L1 |
| 4.b | Explain nuclear reaction? Explain the nuclear fission process. | [4] | CO2 | L1 |
| 5.a | Define substation? Explain the functions of the following components.<br>(i) Transformer (ii)Isolators (iii)Protective relays | [6] | CO3 | L1 |
| 5.b | Briefly discuss the classification of substations. | [4] | CO3 | L1 |
| 6.a | Compare and the advantages and disadvantages of outdoor substations to indoor substations? | [5] | CO3 | L2 |
| 6.b | Give the advantages of neutral grounding? | [5] | CO3 | L2 |
| 7.a | Explain sinking fund method to determine depreciation cost of the power plant. | [5] | CO4 | L1 |
| 7.b | A 300KVA distribution tranformer costs of Rs.20,000 and has a salvage value of Rs.1000 at the end of 20 years.Determine the depreciation value of the plant at the end of 10 years on the following methods of assessment. | [5] | CO4 | L2 |

# ANSWERS

1.




- Reactor is the part of nuclear power plant where nuclear fuel is subjected to nuclear fission and the energy released in the process is utilised to heat the coolant which may in turn generate steam.
- The main function of the reactor is to control the emission and absorption of neutrons.

The main parts of reactor are

- **Reactor core, Moderator, Control rods, Coolant, Reflector, Thermal Shielding, Reactor vessel, Biological shield.**

**Reactor core**

- The reactor core mainly comprises of a number of rods made of fissile materials.
- In a view to have better control of the fission reaction, it is usually to clad the fuel with aluminium or zirconium or stainless steel.
- The fuel is finely powdered and shaped into a form which facilitates uniform production of heat.
- It is then enclosed inside the cladding material, and the cladded fuel is suitably placed inside the reactor.

**Moderator**

- The purpose of moderator is to **slow down the fast moving secondary neutrons, so that chain reaction is sustained.**
- The moderator surrounds the fuel rods.
- As soon as fast moving neutrons are given out, as a result of chain reaction they collide against the moderator and slow down.
- They are now capable of causing further fission, and thus the chain reaction continues.
- Materials used as moderators are ordinary **water, heavy water, beryllium and graphite.**
- **Moderator should have high scattering cross section and low neutron absorption cross section**

**Control rods**

- Control rods are meant for **controlling the rate of fission of U 235.**
- Control rods are rods, plates, or tubes containing a **neutron absorbing material** which are made of boron, cadmium etc, that absorb some of the slowed neutrons.
- **Chain reaction is controlled either by removing the control rods(to increase reaction) or by inserting it to decrease the reaction**.
- The materials used for control rods must have **very high absorption capacity for neutrons.**
- If the fissioning rate of the chain reaction is to be increased, the control rods are moved out slightly so that they absorb less number of neutrons & vice versa.

**Coolant**

- It is a **medium through which the heat generated in the reactor is transferred to the heat generator for further utilization of power generation**.
- If water is used as coolant it takes up heat & gets converted into steam in the reactor which is directly used for driving the turbine.

- A good coolant should not absorb neutrons, should be non oxidising, non toxic & non corrosive and have high chemical and radiation stability and good heat transfer ability.
- **Gases : Air, helium, hydrogen & CO2**
- **Liquids : Light & heavy water.**
- **Metals : Molten sodium & Lithium are used as coolants.**
- **Ordinary water is** used both as coolant & moderator in Boiling water reactors.
- **Pressurized water** is used as coolant & moderator in Pressurized water reactors.
- Water has good **thermal capacity and good heat transport medium.**
- **Liquid metals are used as coolant in fast reactors which have large heat release from, a small core.**
- They have **high heat transfer capability & low vapour pressure.**
- **$CO_2$ is colourless & odourless & has low neutron absorption cross section.**
- When dry, it doesn't react with mild steel of the pressure vessel.
- It reacts with graphite so special steps to be taken in the design of reactor so as to inhibit the reaction between $CO_2$ and graphite.

**Reflector**

- A neutron reflector is placed around the core and used to avoid the leakage of neutrons from the core.
- Reflector **sends back any slow moving secondary neutron which tries to escape out of th reactor core .**
- The reflector surrounds the reactor core completely.
- It is made of the same material as the moderator, and possesses the same characteristic feature as the moderator.
- The reflector helps to conserve the nuclear fuel by preventing the escape of the neutrons.

**Thermal shielding**

- The shielding is usually **constructed from iron and help in giving protection from the deadly ά and β particle radiations and ϒ rays as well as neutrons given off by the process of fission with the reactor.**
- In this manner it gets heated and prevents the reactor wall from getting heated and coolant which flows over it takes away this heat.

**Reactor vessel**

- The reactor core, **reflector and thermal shielding are all enclosed in the main body of the reactor and is called the reactor vessel.**
- It is strong walled container and provides the entrance and exit for the coolant and also passages for its flow through and around the reactor core.
- The reactor core is usually placed at the bottom of the vessel.

**Biological shield**

- The whole of the reactor is enclosed in a biological shield to prevent the escape or leak away of the fast neutrons, slow neutrons, β particles and ϒ rays as theses radiations are very harmful for living organisms.
- Lead iron or dense concrete shields are used for this purpose.

**1.b) Merits**

- The amount of fuel required is quite small, therefore there is no problem of transportation, storage etc
- These plants need less area as compared to any other plant of the same size. A 2000 MW nuclear power plant needs about 80 acres whereas the coal fired steam power plant of same capacity needs about 250 acres of land.
- Man power required for the operation of nuclear power plant is less. Therefore the cost of operation is reduced.
- In these plants transportation is not required so it can be located near to the load centres,
- These plants are most economical in large capacity. The output control is extremely flexible i.e, the output can be instantaneously adjusted from zero to upper limit.
- There are large deposits of nuclear fuel available all over the world. Therefore such plants can ensure continued supply of electrical energy for long years.

- **Demerits**
- The initial cost of the power plants will be high as compared to the other types of power plants
- The erection & commissioning of the plant requires greater technical skills.
- The fission by products are generally radio active & may cause a dangerous amount of radioactive pollution
- The fuel used is expensive & difficult to recover.
- The disposal of the products, which are radioactive is a big problem. They have either to be deposed off in a deep trench or in a sea away from sea shore.
- Maintenance charges are high.
- The cooling water requirements of a nuclear power plants are very heavy. Hence cooling towers required for nuclear power plants are larger & costlier than those for conventional steam power plants.

2. According to the application
   - Research and Development Reactors: These reactors are used for testing new reactor designs and research.
   - Production: For converting fertile materials into fissile materials.
   - Power: These reactors are used for generation of electrical energy.

**According to type of fission**

- **Slow reactors**
- Neutron kinetic energy is less than 0.1 eV
- **Intermediate reactors**
- Neutron kinetic energy is between 0.1 eV and 0.1 MeV
- **Fast neutron**
- Neutron kinetic energy 1 MeV or more.

**According to type of fuel used**

- Natural uranium
- Enriched uranium
- Plutonium

**According to state of fuel**

- Solid
- Liquid

**According to fuel cycle**

- **Burner reactor**
- Designed for producing heat only without any recovery of converted fertile material.
- **Converter reactor**
- Such reactors convert fertile material into fissile material different from the one initially fed into the reactor core.
- **Breeder reactor**
- Such reactors convert fertile material into fissile material, which is similar to one initially supplied to the reactor core.
- A breeder reactor is also which convert fertile material into fissile material at a higher value than at which the fissile material is consumed.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**Arrangement of fissile and fertile material**

- **One region**

- Fissile and fertile material mixed
- **Two region**
- Fissile and fertile material separated

**Arrangement of fuel and moderator**

- **Homogeneous reactor**
- Nuclear fuel and moderator represent uniform mixture in the fluid form, including gases, liquids and slurries ( mixture of an insoluble substance, as cement, clay with liquid )
- **Heterogeneous reactor**
- Separate fuel rods are inserted in the moderator in some sort of regular arrangement forming a so called lattice.

**Moderator material**

- **Heavy water**
- **Graphite**
- **Ordinary water**
- **Beryllium**
- **Organic reactors**

**On basis of coolant used**

- **Gas**
- **Water**
- **Heavy water**
- **Liquid metal reactors**

**On basis of cooling system**

- **Direct**
- The liquid fuel circulated from the reactor to heat exchanger where steam is generated**.**
- **Indirect**
- Coolant passed through the reactor and then through the heat exchanger for steam generation

**Power reactors in common use**

- **Boiling Water Reactor**
- **Pressurized Water Reactor**
- **Gas Cooled Reactor**
- **Heavy Water Cooled and Moderated ( CANDU TYPE ) Reactor**
- **Liquid Metal Cooled Reactors**
- **Fast Breeder Reactor**

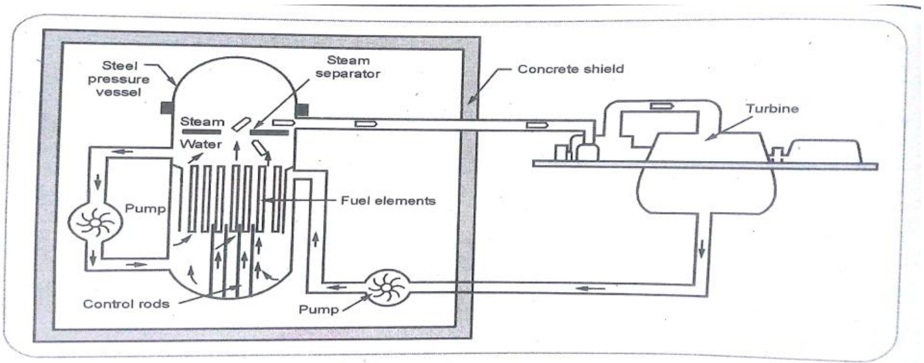



Fig. 5.16.1 Boiling water reactor

- It has a steel pressure vessel surrounded by a concrete shield.
- Fuel used is **enriched uranium oxide**.
- **Ordinary water is used both as moderator and coolant**.
- The steam is generated in reactor itself.
- Feed water enters the reactor vessel at the bottom and takes the heat produced due to fission of fuel and gets converted into steam
- This steam leaves the reactor at the top and after passing through turbine and condenser returns to the reactor.
- Uranium fuel elements are arranged in a **particular lattice form** inside the pressure vessel containing water.
- A BWR assembly comprises 90-100 fuel rods and there are up to 750 assemblies in a core holding up to 140 tonnes of uranium.

**Advantages**

- This includes small size pressure vessel, high steam pressure, simple construction & elimination of heat exchanger resulting in reduction in cost & gain in thermal efficiency.

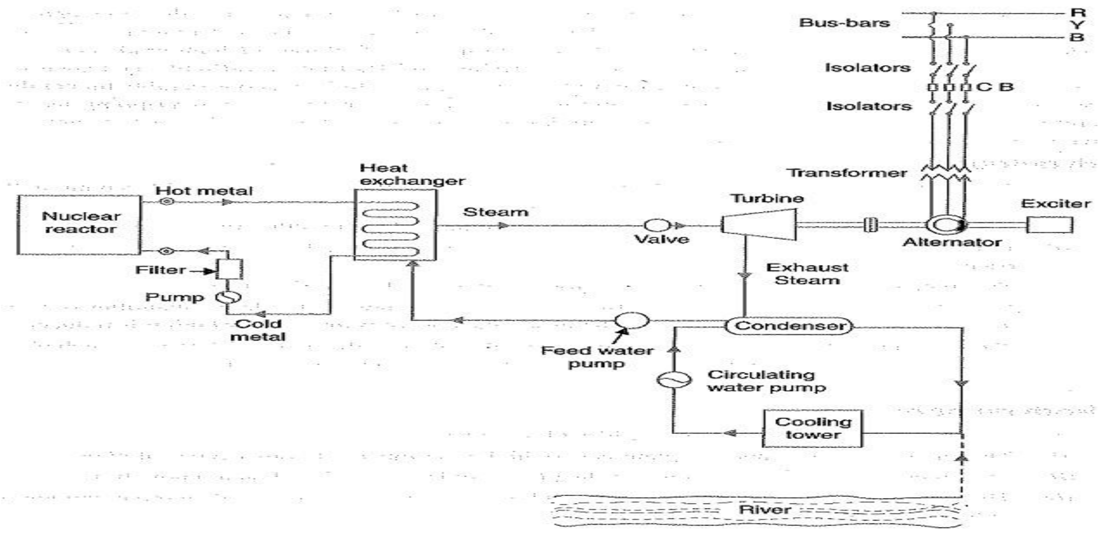
**Disadvantages**

- In view of direct cycle there is a danger of radioactive contamination of steam, therefore more safety measures are provided for piping and turbine.
- It cannot meet sudden increase in load.
- Because of the danger of small amounts of fissile materials passing through along with the steam/water more biological protection is needed.

2.b)

- Fast reactors get more neutrons out of their primary fuel than thermal reactors, so many can be used to breed new fuel, vastly enhancing the sustainability of nuclear power.
- Fast reactors are capable of destroying the longest-lived nuclear waste, transforming it to waste that decays to harmlessness in centuries rather than hundreds of millennia.
- Fast reactors typically use liquid metal coolants rather than water.
- These have superior heat-transfer properties and allow natural circulation to remove the heat in even severe accident scenarios.

3.a)




- The concepts of Nuclear power generation are much similar to that of conventional steam generation.
- The difference lies only in the steam generation part i.e coal furnace & Boiler are been replaced by the Nuclear reactor and Heat exchanger.

The nuclear power plant consists of a

- **Nuclear reactor : For heat generation**
- **Heat exchanger : For converting water into steam by using the heat generated in Nuclear reactor.**
- Followed by steam turbine, alternator, condenser etc.
- The reactor and the cooling circuit have to be shielded to eliminate radiation hazards.
- The tremendous amount of heat energy produced in breaking of atoms uranium or other similar metals by fission process in an atom reactor is extracted by pumping fluid or molten metal like liquid sodium or gas through the pile.
- The heated metal or gas is then allowed to exchange its heat to the heat exchanger by circulation.
- In steam generator steam is generator which are utilised to drive the turbine coupled to alternator thereby generating electrical energy.
- While deciding the layout of a nuclear power plant due consideration should be given to safety, operation convenience & capital economy.
- One of the important operational areas in a reactor building is the charge hall which is used for refueling operation.
- The main parts of nuclear power plant are Nuclear reactor, turbine, alternator, hence the layout is simple.
- A main control room is provided in a central location & consists of all necessary equipment's for the operation.
- All other auxiliary rooms such as charge room maintenance room, store, machine shop, switchyard, railway siding etc are suitably located for convenient operation.

3.b) **Selection of site**

- **Availability of Water Supply**

- Sufficient water is required for cooling etc, therefore the site selected should be nearer to river , lake etc
- **Distance from populated area**
- The nuclear plant should be located away from populated area because of the presence of radio activity in the atmosphere near the plant. However as precautionary a dome is used in the plant which does not allow the radio activity to spread.
- **Transportation Facilities**
- A nuclear plant requires very little fuel, hence it does not require direct rail facilities for fuel transport. However, transportation to be needed during construction stage.
- **Nearness to Load centre**
- Plants should be nearer to load centre as possible, in order to reduce transmission costs.
- **Availability of Space for Disposal of Waste**
- The site selected for such power plants should have adequate space & arrangement for the disposal of radio active waste
- **Type of Land**
- The foundation must be strong enough to support the heavy reactors which may weigh as high as 1,00,000 tonnes & impose bearing pressure around 50 tonnes/$m^2$ .

4.a) **Disposal of nuclear waste and effluent**

- Solid radioactive wastes arise from used filters, sludge from the cooling ponds, pieces of discarded fuel element cans, splitters etc.
- These discarded items of plants such as control rods have to be stored on site in **shielded concrete vaults.**
- The storing in shielded storage vaults consists of fixing the solid waste in **borosilicate glass and then storage of this glass in leak tight capsules.**
- These capsules or vaults cab then be stored in deep salt mines or in deep wells drilled in the stable ocean floor.
- Sometimes, **suitable containers are filled with radioactive waste and sunk to the bottom of seas and oceans.**
- Another way of disposal is the **separation and transmutation of the long lived isotopes to short-lived or stable products following neutron absorption in a breeder or fusion reactor.**
- It is safe enough to store radioactive waste underground in liquid form in suitable tanks or in reduction to clinker ( Stony residue )
- Clinkering serves a two fold purpose of improving the protection and reducing the volume of waste.
- One more method is "**solidifying**" the liquid radioactive waste through heat up and evaporation.
- Gaseous effluents are filtered before discharging into atmosphere. Moreover, the filtered gas is discharged at high levels so that it is dispersed properly.
- The probability of fire in the reactor fuel channel is extremely low. However, if fire breaks out, large volumes of gaseous fission products may be released.
- So it is necessary to have a **clean up plant through which theses products can be passed for removal of radioactive iodine which is the main hazard.**

**Shielding**

- Adequate shielding is necessary to guard personnel and delicate instruments.
- The various materials used for shielding are **lead, concrete, steel and cadmium.**
- **Lead** is a common shielding material and is invariably employed due to its low cost.
- **Concrete** is another shielding material having efficiency lesser than that of lead.
- **Steel** is not an efficient shielding material but has good structural properties and is sometimes employed as an attenuating shield.
- **Cadmium** is capable of absorbing slow neutrons by a nuclear reaction.
- A material containing hydrogen e.g water or polythene is used to slow down fast neutrons.
- Boron or steel is employed for absorption of thermal neutrons.
- A heavy material like lead is required to act as a thermal shield and absorb gamma rays.
- In nuclear power reactors a thermal shield of thickness of several cms of steel surrounded by about 3 m thick concrete is used.

4.b) a **nuclear reaction** is semantically considered to be the process in which two nuclei, or else a nucleus of an atom and a subatomic particle (such as a proton, neutron, or high energy electron) from outside the atom, collide to produce one or more nuclides that are different from the nuclide(s) that began the process. Thus, a nuclear reaction must cause a transformation of at least one nuclide to another. If a nucleus interacts with another nucleus or particle and they then separate without changing the nature of any nuclide, the process is simply referred to as a type of nuclear scattering, rather than a nuclear reaction.

In principle, a reaction can involve more than two particles colliding, but because the probability of three or more nuclei to meet at the same time at the same place is much less than for two nuclei, such an event is exceptionally rare. "Nuclear reaction" is a term implying an **induced** changing in a nuclide, and thus it does not apply to any type of radioactive decay.

Natural nuclear reactions occur in the interaction between cosmic rays and matter, and nuclear reactions can be employed artificially to obtain nuclear energy, at an adjustable rate, on demand. Perhaps the most notable nuclear reactions are the nuclear chain reactions in fissionable materials that produce induced nuclear fission, and the various nuclear fusion reactions of light elements that power the energy production of the Sun and stars.

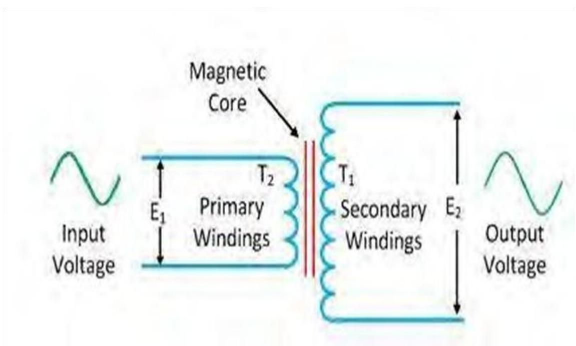
## 5.8 Nuclear Fission Process

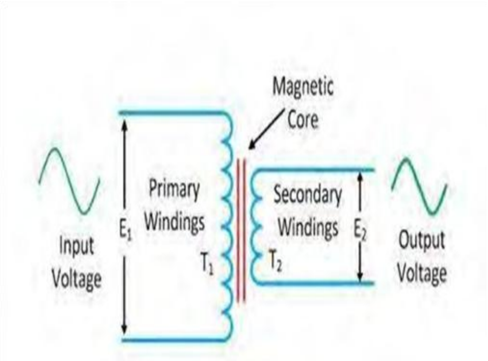
- Nuclear fission is the process of splitting apart nuclei (usually large nuclei). In other words, *nuclear fission is a nuclear reaction in which the nucleus of an atom splits into smaller parts (lighter nuclei). This nuclear reaction is triggered by the neutron.* When large nuclei, such as uranium-235, fissions, energy is released. The amount of energy released is so large that there corresponds a measurable decrease in mass, from the mass-energy equivalence. This means that some of the mass is converted to energy. The amount of mass lost in the fission process is equal to about $3.20\times10^{-11}$ J of energy. This fission process generally occurs when a large nucleus that is relatively unstable (meaning that there is some level of imbalance in the nucleus between the Coulomb force and the strong nuclear force) is struck by a low energy thermal neutron. In addition to smaller nuclei being created when fission occurs, fission also releases neutrons.
- The fission of U-235 in reactors is triggered by the absorption of a low energy neutron, often termed a "slow neutron" or a "thermal neutron". Other fissionable isotopes which can be induced to fission by slow neutrons are plutonium-239, uranium-233, and thorium-232.

- 5.a) A **substation** is a part of an **electrical generation, transmission, and distribution system.**
- Substations transform voltage from high to low, or the reverse, or perform any of several other important functions.
- Between the generating station and consumer, electric power may flow through several substations at different voltage levels.
- A substation may **include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages.**
- Some substations are simply **switching stations** where different connections between various transmission lines are made.
- The other stations are **converting stations** which either convert ac into dc or vice versa or convert frequency from higher to lower or vice versa.
- Substations include safety devices to disconnect the equipment or circuit in the event of fault.
- Voltage on the outgoing distribution feeders can be regulated at substation.

**Transformers**

- A transformer is a static device which transforms electric power from one circuit to another circuit without the change in frequency. It depends on Faraday's Law of Electromagnetic Induction.
- Step up transformer : A transformer in which the output (secondary) voltage is greater than its input (primary) voltage is called a step-up transformer.




- **Step down transformer** : A transformer in which the output (secondary) voltage is less than its input (primary) voltage is called a step-down transformer.

**Isolator**

- Circuit Breaker always trip the circuit but open contacts of breaker cannot be visible physically from outside of the breaker.
- So for better safety there must be some arrangement so that one can see open condition of the section of the circuit before touching it.
- Isolator is a mechanical switch which isolates a part of circuit from system as when required.
- Electrical isolators separate a part of the system from rest for safe maintenance works.
- **Isolator is a manually operated mechanical switch which separates a part of the electrical power.**

**Protective Relaying**

- A protective relay is a **device that detects the fault and initiates the operation of the circuit breaker to isolate the defective element from the rest of the system.**
- The relays detect the abnormal conditions in the electrical circuits by **constantly measuring the electrical quantities** which are different under normal & fault conditions.
- Electrical quantities which may change in fault conditions are V, I, frequency & phase angle.
- Having fault detected the fault, the relay operates to close the trip circuit of the breaker.
- This results in the opening of the breaker & disconnection of the faulty circuit.

5.b) **Classification of Substation**

- **Indoor type substation**
- **Outdoor type substation**
- **Indoor type substation**
- In these substations the apparatus is installed within the substation building.
- Such substation are usually for a **voltage up to 11KV but can be erected for 33KV and 66KV volts** when surrounding atmosphere is contaminated with impurities such as metal corroding gases and fumes, conductive dust etc.
- The several compartments in which the indoor station is divided are
- **Control compartment**
- **Indicating and metering instruments**
- **Protective device compartment**
- **Circuit breaker and operating mechanism compartment**
- **Main bus compartment**
- **Current transformer and cable sealing box compartment**

- **Indoor distribution & transformer substations as well as high switchboards** consist of a series of open and enclosed chambers or compartments.

According to construction indoor distribution substations & high voltage switchboards are further divided into following categories.

- **Substations of the integrally built type**
- The apparatus is installed on site. In such substations the cell structure are constructed of concrete.
- **Substations of the Composite build up type**
- The compartments of such substations take form of metal cabinets or enclosures, each of which contains the equipment of one main connection cell.
- **Unit type factory fabricated substations and metal clad switchboards**
- This will be designed with the metal clad cubicles
- **Outdoor Substations**
- **Pole Mounted Substations**
- **Foundation Mounted Substations**

**Pole Mounted Substations**

- These substations are erected for mounting distribution transformers of capacity up to 250 KVA.
- They are cheapest, simple & smallest of substations.
- All the equipment is mounted on the supporting structure of **HT distribution line**.
- Triple pole mechanical operated switch is used for switching on & off of ht transmission line.
- HT fuse is installed for protection of HT side.
- Lightning arrestors are installed over the ht line to protect the transformers from surges.
- Transformers of capacity up to 1**25KVA** are mounted on double pole structure.
- Transformers of capacity above **125 KVA & below 250 KVA** are mounted on 4 pole structure.
- The maintenance cost of theses substations is low.

**Foundation Mounted Substations**

- Theses substations are entirely in the open and in such substations all the equipment is assembled into one unit usually enclosed by a fence from the point of view of safety.
- The **primary and secondary transmission and for secondary distribution (above 250 KVA) are foundation mounted outdoor type.**
- The equipment's are heavy for such substations, therefore site selected for theses substations must have good access for heavy transport.
- They may be of two types low type and high type.

6.a) **Advantages and Disadvantages of outdoor substations Over Indoor substations**

- **Advantages**
- All the equipment is within view and therefore fault location is easier.
- The extension of the installation is easier
- The small amount of building materials
- The construction work required is comparatively smaller and cost of the switchgear installation is low.
- Repairing work is easy.
- Sufficient space between equipments
- **Disadvantages**
- More space is required for the substation
- Protection devices are required to be installed for protection against lightning surges.
- The length of control cable required is more.
- Since the equipment's are exposed to the atmosphere, there would be accumulation of dust and dirt on them.
- During the rainy season, switching operations may be difficult.

6.b) **Advantages of neutral earthing**

- Earth fault protection can be used easily
- The high voltages due to transient line to ground fault are eliminated

- Neutral earthing reduces the impact of lightning by discharging the stroke to earth
- Greater safety to the personnel
- It provides stable neutral point
- It improves reliability, economy and performance of the system

7.a)

**(iii) Sinking fund method:** In this method, a fixed depreciation charge is made every yea and interest compounded on it annually.The constant **depreciation charge** is such that total c annual instalments plus the interest accumulations equal to the cost of replacement c equipment after its useful life.

**Must Read:**

- 

Let P = Initial value of equipment

n = Useful life of equipment in years

S = Scrap value after useful life

r = Annual rate of interest expressed as a decimal

Let us suppose that an amount of $q$ is set aside as depreciation charge every year and interest compounded on it so that an amount of $P - S$ is available after $n$ years. An amount $q$ at annual interest rate of $r$ will become $*q(1 + r)^n$ at the end of $n$ years.

Now, the amount $q$ deposited at the end of first year will earn compound interest for $n - 1$ years and shall become $q(1 + r)^{n-1}$ *i.e.*,

Amount $q$ deposited at the end of first year becomes

$$= q\,(1 + r)^{n-1}$$

Amount $q$ deposited at the end of 2nd year becomes

$$= q\,(1 + r)^{n-2}$$

Amount $q$ deposited at the end of 3rd year becomes

$$= q\,(1 + r)^{n-3}$$

Similarly amount $q$ deposited at the end of $n - 1$ year becomes

$$= q\,(1 + r)^{n-(n-1)}$$

$$= q\,(1 + r)$$

$$\therefore \quad \text{Total fund after } n \text{ years} = q\,(1 + r)^{n-1} + q\,(1 + r)^{n-2} + .... + q\,(1 + r)$$

$$= q\,[(1 + r)^{n-1} + (1 + r)^{n-2} + .... + (1 + r)]$$

This is a G.P. series and its sum is given by :

$$\text{Total fund} = \frac{q(1 + r)^n - 1}{r}$$

This total fund must be equal to the cost of replacement of equipment P – S.

$$\therefore \quad P - S = q\frac{(1 + r)^n - 1}{r}$$

$$\text{or} \quad \text{Sinking fund, } q = (P - S)\left[\frac{r}{(1 + r)^n - 1}\right]$$

The value of 'q' gives the uniform annual **depreciation charge**.The parenthetical term in ec (i) is frequently referred to as the "sinking fund factor".

$$\therefore \qquad \text{Sinking fund factor} = \frac{r}{(1+r)^n - 1}$$

Though this method does not find very frequent application in practical depreciation accountinç it is the fundamental method in making economy studies and most effective **method c determining depreciation**.

7.b)

**Ex. 8.9.3 :** The equipment in a power station costs ₹ 15, 60,000 and has a salvage value of ₹ 60,000 at the end of 25 years. Determine the depreciated value of the equipment at the end of 20 years on the following methods :

**1. Straight line method ;**

**2. Diminishing value method ;**

**3. Sinking fund method at 5 % compound interest annually.**

**Sol. :** Initial cost of equipment, P = ₹ 15, 60,000

Salvage value of equipment, S = ₹ 60,000

Useful life, n = 25 years

**Straight line method**

$$\text{Annual Depreciation} = \frac{P-S}{n} = ₹\ \frac{1560000-60000}{25} = ₹\ 60000$$

$$\text{Value of equipment after 20 years} = P - \text{Annual depreciation} \times 20$$

$$= 15,60,000 - 60,000 \times 20$$

$$= ₹\ 3,60,000$$

**Diminishing value method**

$$\text{Annual Unit Depreciation } x = 1 - \left(\frac{S}{P}\right)^{\frac{1}{n}}$$

$$= 1 - \left(\frac{60000}{1560000}\right)^{\frac{1}{25}}$$

$$= 1 - 0.878 = 0.122$$

Value of equipment after 20 years

$$= P(1-x)^{20}$$

$$= 15,60,000\,(1-0.122)^{20}$$

$$= ₹\ 1,15,615$$

**3. Sinking fund method**

Rate of interest, $r = 5\ \% = 0.05$

$$\text{Annual deposit in the sinking fund is } q = (P - s)\left[\frac{r}{(1+r)^n - 1}\right]$$

$$= (15,60,000 - 60,000)\left[\frac{0.05}{(1+0.05)^{25} - 1}\right]$$

$$= ₹\ 31,433$$

So, sinking fund at the end of 20 years

$$= q\,\frac{(1+r)^{20} - 1}{r}$$

$$= 31,433\,\frac{(1+0.05)^{20} - 1}{0.05}$$

$$= ₹\ 10,39,362$$

alue of plant after 20 years = ₹ (15, 60, 000 – 10, 39, 362)

$$= ₹\ 5,20,638$$